Mapping the connectivity of large-scale coastal geomorphological systems: Coastal system mapping with CmapTools tutorial

Science Report: SC060074/PR2

Product code: SCHO0809BQVK-E-P
The Environment Agency is the leading public body protecting and improving the environment in England and Wales.

It’s our job to make sure that air, land and water are looked after by everyone in today’s society, so that tomorrow’s generations inherit a cleaner, healthier world.

Our work includes tackling flooding and pollution incidents, reducing industry’s impacts on the environment, cleaning up rivers, coastal waters and contaminated land, and improving wildlife habitats.

This report is the result of research commissioned by the Environment Agency’s Science Department and funded by the joint Environment Agency/Defra Flood and Coastal Erosion Risk Management Research and Development Programme.
Science at the Environment Agency

Science underpins the work of the Environment Agency. It provides an up-to-date understanding of the world about us and helps us to develop monitoring tools and techniques to manage our environment as efficiently and effectively as possible.

The work of the Environment Agency’s Science Department is a key ingredient in the partnership between research, policy and operations that enables the Environment Agency to protect and restore our environment.

The science programme focuses on five main areas of activity:

- **Setting the agenda**, by identifying where strategic science can inform our evidence-based policies, advisory and regulatory roles;
- **Funding science**, by supporting programmes, projects and people in response to long-term strategic needs, medium-term policy priorities and shorter-term operational requirements;
- **Managing science**, by ensuring that our programmes and projects are fit for purpose and executed according to international scientific standards;
- **Carrying out science**, by undertaking research – either by contracting it out to research organisations and consultancies or by doing it ourselves;
- **Delivering information, advice, tools and techniques**, by making appropriate products available to our policy and operations staff.

Steve Killeen

**Head of Science**
Executive summary

This document provides a tutorial for a new methodology for mapping the structure and connectivity of large-scale coastal geomorphological systems that has been developed as part of an Environment Agency funded project: *Characterisation and prediction of large scale, long-term change of coastal geomorphological behaviours.*
Acknowledgements

The authors acknowledge useful discussions with the other members of the project team at HR Wallingford, Royal Haskoning, University of Southampton, Kenneth Pye Associates Ltd, University of Newcastle, British Geological Survey, and from Tim Kermode and Stefan Laeger of the Environment Agency. The report was reviewed by Richard Whitehouse (SC060074 Project Manager) at HR Wallingford.
Contents

1 Introduction 1
  1.1 Background 1
  1.2 Purpose of coastal system mapping 1
  1.3 Coastal system mapping using CmapTools software 1
  1.4 Note on alternative platforms 2

2 Principles of coastal system mapping 3
  2.1 Hierarchical feature-element classification 3
  2.2 Alongshore versus cross-shore zonation 4
  2.3 System linkages: sediment budgets and influences 5
  2.4 Mapping conventions 5

3 Worked example: Alnmouth Bay, northeast England 10
  3.1 Alnmouth Bay 10
  3.2 CmapTools software installation and start-up 12
  3.3 Concluding remarks 23

4 Frequently-asked questions 24

5 References 25

Table 2.1 Summary of coastal feature set 3
Table 2.2 Summary of coastal element set. Note the inclusion of various types of intervention (including non-structural management interventions) 4

Figure 2.1 Convention for coastal system mapping 6
Figure 2.2 Flow chart for coastal system mapping procedure 9
Figure 3.1 Alnmouth Bay. Rectangle shows region of interest for tutorial example (image from Google Maps) 11
Figure 3.2 Southern part of Alnmouth Bay used in tutorial (image from Google Maps) 12
Figure 3.3 CmapTools explorer menu (displayed on startup) and untitled map window 13
Figure 3.4 New map window 14
Figure 3.5 Cmap window for the Alnmouth map, with imported background image, and Style Palette for system objects 14
Figure 3.6 Addition of labels for principal features, including ‘Mouse Over Info’ for the Birling Carrs headland 15
Figure 3.7 Addition of labels for principal elements of the Birling Carrs headland and the southern portion of Alnmouth Bay. Note use of correct ellipsoidal ‘element’ symbols 16
Figure 3.8 Mapping of elements and interventions for the Coquet River estuary and Amble headland 17
Figure 3.9 Creation of a ‘nested node’ to group the component parts of the bay feature (which have previously been selected) 18
Figure 3.10 Newly-created bay feature, prior to formatting using Style Palette 18
Figure 3.11 Creating a link between high ground (hinterland) and dune (backshore). Style Palette Line tab can be used to determine whether to draw arrowheads always (first option), under various conditions (options 2 and 3), or not to draw arrowheads (option 4; as indicated in figure). Directionality can also be determined once a given link is selected 19
Figure 3.12 Completed link mapping for the example system. Note use of solid and dashed lines for sediment and influence links and arrows to indicate direction of influence 20
Figure 3.13 Rationalised map, with beach and dune elements of bay merged to preserve the essential structure of the system using the minimum number of elements 21
Figure 3.14 Linking of digital photograph resources to a specific system component using the Add & Edit Links to Resources option 22
Figure 3.15 Viewing embedded photographic resources by selecting from list associated with system component. Image resource is associated with jetty structure (image courtesy of Royal Haskoning) 22
1 Introduction

1.1 Background

This document provides a tutorial for a new methodology for mapping the structure and connectivity of large-scale coastal geomorphological systems that has been developed as part of an Environment Agency funded project: *Characterisation and prediction of large scale, long-term change of coastal geomorphological behaviours*. The project ran from 2007 to 2009 and was undertaken by a consortium comprising: HR Wallingford, Royal Haskoning, University College London, University of Southampton, Kenneth Pye Associates, University of Newcastle and British Geological Survey. Further background information can be obtained from the project website at: [www.coastalgeomorphology.net](http://www.coastalgeomorphology.net)

1.2 Purpose of coastal system mapping

System mapping provides a means of synthesising and formalising scientific understanding of large-scale coastal behaviour. It is a form of knowledge formalisation that allows disparate sources of information (or 'plain data') to be converted into usable knowledge and a more systematic understanding. The resulting maps provide an efficient and highly effective means of encapsulating and communicating scientific understanding in the form of a conceptual model of coastal system behaviour. Coastal system maps also provide a framework for the deployment of predictive models capable of analysing and simulating large-scale and long-term coastal morphodynamics. In particular, they allow identification of sediment sources, stores and sinks, and define the connectivity of interacting coastal and estuary sub-systems.

Coastal system mapping is particularly effective as a 'brainstorming' tool. For example, it can be used as part of a project workshop to develop a consensus understanding based on the experience and views of all the participants. The latter might include recognised scientific experts (who might guide the process), as well as managers and stakeholders (who might contribute valuable qualitative knowledge on specific aspects of coastal behaviour). It should be noted that knowledge formalisation is a subjective process, and is therefore unrealistic to think in terms of a single coastal system map that is ‘valid’ for all applications. Even expert geomorphologists will invariably interpret data and scientific literature differently. This can actually be an advantage, since differences between maps produced by individual experts can highlight areas of consensus or robust understanding, and areas of disagreement or weak understanding that might require more detailed study.

1.3 Coastal system mapping using CmapTools software

In principle, conceptualisation of a system in terms of a set of discrete components and the representation of the interactions between these components in diagrammatic form can be undertaken as a pencil and paper exercise. For all but the simplest system, however, mapping is more easily accomplished with the aid of specialist computer software. This tutorial document describes the use of CmapTools software.
CmapTools is available as freeware from: http://cmap.ihmc.us. It was developed to aid the production of ‘concept maps’, which are graphical tools for organizing and representing knowledge. Here, we use CmapTools mainly as a convenient interactive tool for constructing coastal system diagrams. However, this software does have functionality that is particularly useful for the mapping of geomorphological systems, notably the ability to attach metadata to system components. This can be used to append additional information on individual system components; this might include geographical information (e.g. coastal chainage or geographical co-ordinates) as well as images, research reports and scientific papers pertaining to specific locations.

This tutorial document sets out some basic rules for the mapping of coastal systems in diagrammatic form, and then shows how such maps can be produced using CmapTools software. The CmapTools tutorial comprises a worked example of the mapping procedure applied to a small section of coast in northeast England. More detail on that example application and two other stretches of coast where the approach has been applied is given in Whitehouse et al. (2009).

The files used in this tutorial can be downloaded from the project website at:

www.coastalgeomorphology.net

or from:

www.geog.ucl.ac.uk/ceru/cmap

1.4 Note on alternative platforms

By adopting the principles and conventions described in Section 2, system mapping can be carried out as ‘paper and pencil’ exercise or within other appropriate software platforms that may be identified by the user, including standard Geographical Information Systems (GIS).
2 Principles of coastal system mapping

This section sets out some general principles that provide a logically-consistent basis for large-scale geomorphological system mapping.

2.1 Hierarchical feature-element classification

At a large-scale (i.e. at the scale of the existing cells or sub-cells for the coast of England and Wales), the organisation of the coastal system is defined with reference to a set of high-level features. Each feature contains a set of lower-level elements. Features and elements are typically connected by sediment transfer pathways, which define the sediment budget system. Divergences, or breaks, in the continuity of the drift system define sub-cell or cell boundaries.

The logic behind the selection of features and elements (and descriptions of each type) are given in Whitehouse et al. (2008, 2009). The list of features is summarised here in Table 2.1 and the elements in Table 2.2. In brief, features include larger-scale headlands, bays, stretches of open coast etc. Elements contain component landforms such as beach, tidal flat, dune, cliff etc. A variety of structural (e.g. seawall) and non-structural (e.g. beach re-profiling) interventions are also identified at the element scale.

Table 2.1 Summary of coastal feature set

<table>
<thead>
<tr>
<th>Feature</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore</td>
<td>Offshore feature used to group seabed types and banks (both of which are considered to interact at the element scale)</td>
</tr>
<tr>
<td>Open coast</td>
<td></td>
</tr>
<tr>
<td>Headland</td>
<td></td>
</tr>
<tr>
<td>Bay</td>
<td></td>
</tr>
<tr>
<td>Spit</td>
<td></td>
</tr>
<tr>
<td>Cuspate foreland</td>
<td></td>
</tr>
<tr>
<td>Inlet</td>
<td></td>
</tr>
<tr>
<td>Tombolo</td>
<td></td>
</tr>
<tr>
<td>Barrier island</td>
<td></td>
</tr>
<tr>
<td>Island</td>
<td>Used to define non-barrier islands that are not mapped in detail but which exert an influence on the coast</td>
</tr>
<tr>
<td>Estuary</td>
<td></td>
</tr>
<tr>
<td>River</td>
<td></td>
</tr>
<tr>
<td>Updrift coast</td>
<td>Used to bound part of larger littoral drift system</td>
</tr>
<tr>
<td>Downdrift coast</td>
<td></td>
</tr>
</tbody>
</table>
Table 2.2  Summary of coastal element set. Note the inclusion of various types of intervention (including non-structural management interventions)

<table>
<thead>
<tr>
<th>Element</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cliff</td>
<td></td>
</tr>
<tr>
<td>Dune</td>
<td></td>
</tr>
<tr>
<td>Lagoon</td>
<td></td>
</tr>
<tr>
<td>Beach</td>
<td></td>
</tr>
<tr>
<td>Shore platform</td>
<td></td>
</tr>
<tr>
<td>Tidal flat</td>
<td></td>
</tr>
<tr>
<td>Saltmarsh</td>
<td></td>
</tr>
<tr>
<td>Channel</td>
<td>Classification of banks follows Dyer and Huntley (1999)</td>
</tr>
<tr>
<td>Inlet-associated bank</td>
<td></td>
</tr>
<tr>
<td>Headland-associated bank</td>
<td></td>
</tr>
<tr>
<td>Offshore bank</td>
<td></td>
</tr>
<tr>
<td>Beach ridge</td>
<td></td>
</tr>
<tr>
<td>Offshore reef</td>
<td></td>
</tr>
<tr>
<td>Seabed sand</td>
<td></td>
</tr>
<tr>
<td>Seabed gravel</td>
<td>Implies low-lying hinterland that has been marine-influenced during Holocene; potentially re-activated by sea-level rise or breakdown of coastal barriers.</td>
</tr>
<tr>
<td>Low ground</td>
<td>Implies land above present tidal influence and which has not been marine-influenced during Holocene; a potential sediment source.</td>
</tr>
<tr>
<td>High ground</td>
<td></td>
</tr>
<tr>
<td>Intervention</td>
<td></td>
</tr>
<tr>
<td>Seawall</td>
<td>Structure</td>
</tr>
<tr>
<td>Revetment</td>
<td>Structure</td>
</tr>
<tr>
<td>Detached breakwater</td>
<td>Structure</td>
</tr>
<tr>
<td>Long terminal groyne or jetty</td>
<td>Structure</td>
</tr>
<tr>
<td>Reclamation embankment</td>
<td>Structure</td>
</tr>
<tr>
<td>Groynes</td>
<td>Structure</td>
</tr>
<tr>
<td>Outlet</td>
<td>Structure</td>
</tr>
<tr>
<td>Weir</td>
<td>Structure</td>
</tr>
<tr>
<td>Sediment recharge</td>
<td>Management intervention</td>
</tr>
<tr>
<td>Sediment bypassing</td>
<td>Management intervention</td>
</tr>
<tr>
<td>Sediment recycling</td>
<td>Management intervention</td>
</tr>
<tr>
<td>Beach re-profiling</td>
<td>Management intervention</td>
</tr>
<tr>
<td>Tide locking</td>
<td>Management intervention</td>
</tr>
</tbody>
</table>

2.2  Alongshore versus cross-shore zonation

At a feature scale, coastal systems are essentially linear in character. Features therefore generally pick out the main alongshore characteristics. Cross-shore zonation is mapped at the element scale, and this extends over the presently active offshore – nearshore – backshore zones as well as the hinterland (which might contain relict coastal and estuarine landforms).

Hinterland elements thus define a potential zone of coastal influence, that includes contemporary coastal processes as well as reflecting the spatial ‘envelope’ of marine and coastal influence during the Holocene and likely behaviour in the near future. Classification of hinterland as low ground is taken to imply that the envelope of Holocene coastal influence extends inland, as represented by contemporary fresh and
brackish wetlands, reclaimed land etc. High ground implies the absence of relict Holocene coastal environments, but indicates potential sediment sources that might be utilised (or activated) according to coastal erosion or the removal of structures.

At some locations, it may be appropriate to recognise a more complex cross-shore zonation. Barrier islands, for example, might contain beach, dune, tidal flat etc, and be backed by channels and further tidal flat, saltmarsh, seawall etc.

2.3 System linkages: sediment budgets and influences

The various component landforms and engineered structures are connected by two kinds of link. Sediment transfer links define long-term average movements of sediment. Influence links represent interactions where no exchange of sediment is involved – for example, the influence of a seawall on the beach (and vice-versa). Linkages can be directional (either one-way or two-way) or left undefined where we do not have enough information to assign a clear preferred direction. Where the sediment budget is well understood, the relative magnitude of the fluxes by weighting the line thickness. In this case, the system map becomes a tool for displaying sediment budget information in a qualitative or semi-quantitative way.

In some situations, separate sediment and influence links must be defined. For example, a coastal bank may receive sediment from a headland (a mass flux) whilst also reducing wave energy along its landward coast (an influence). Curved links can be used in these cases to avoid overlapping lines.

2.4 Mapping conventions

It is important that system maps adopt a consistent symbolic representation. The scheme presented in Figure 2.1 is designed to be generic and is not specific to any particular software. However, all the graphical components shown can be created in the CmapTools package that is described in this tutorial.

Key aspects of the mapping scheme include:

- a symbolic distinction between Features, Elements and Interventions.
- a distinction between features that are mapped completely and those that are partially mapped (e.g. estuaries included in a broader coastal map but not represented in detail for reasons of clarity).
- a distinction between sediment and influence links and the ability to represent both the direction and relative strength of these.

Depending on the application, it is necessary to decide whether to arrange the system components in a geographical map, scaled against real-world co-ordinates, or in the form of a topological map, which may be more visually communicative. Geographical maps can be constructed on top of a base map or image of a region of interest. This is convenient for short stretches of coast (e.g. a single bay-headland system) for which high quality aerial imagery is available. Topological maps may be better for larger systems, where the map must convey a great deal of information and where the structure of the system is more important than the actual location of the components.
Figure 2.1 Convention for coastal system mapping

**Feature**
- solid rectangle, upper case text
- optional colour-coded shading

**ESTUARY**
Partially mapped feature-level sub-system
- dashed rectangle, upper case text
- optional colour-coded shading

**Element**
- solid ellipse, lower case text
- optional colour-coded shading

**Intervention**
- solid rounded rectangle lower case text
- white text on black background

**Feature set (contains elements and interventions)**
- solid rectangle for completely mapped feature

- dashed rectangle used to enclose partially-mapped feature (e.g. an estuary, for which all the internal linkages are omitted for clarity in a larger coastal map)

**Seaton Point**
Geographical place name
- Bold, no enclosing object

<table>
<thead>
<tr>
<th>Mass transfer links (sediment pathways)</th>
<th>Influence links</th>
</tr>
</thead>
<tbody>
<tr>
<td>---------</td>
<td>---------------</td>
</tr>
<tr>
<td>uncertain direction</td>
<td>--</td>
</tr>
<tr>
<td>uni-directional</td>
<td>--</td>
</tr>
<tr>
<td>bi-directional</td>
<td>--</td>
</tr>
<tr>
<td>(optionally)</td>
<td>weak</td>
</tr>
<tr>
<td></td>
<td>strong</td>
</tr>
</tbody>
</table>
**Stages in the production of a coastal system map**

The key stages in the production of a coastal system map are summarised below and diagrammatically in Figure 2.2. Although reference is made to CmapTools software, the procedure is essentially generic and could be adapted for other software or used as a basis for ‘pencil and paper’ mapping.

**Stage 1: Specify region of interest and define problem**

First, specify a region of interest. For England and Wales, a useful framework already exists in the form of coastal cells and sub-cells; these may help to determine a meaningful region of interest. Next, define the nature of the problem. This might be part of a ‘brainstorming’ exercise to synthesize expert opinion on the behaviour of a given stretch of coast; it might be a requirement to undertake broad-scale mapping as a framework for modelling; or it may stem from a need to provide context for more local management decision-making (e.g. the evaluation of alternative management options for an estuary mouth in the context of wider aspects of estuary-coast interaction).

**Stage 2: Decide how the mapping process will be undertaken**

Decide on whether mapping is to be carried out as a consensus-building exercise involving a large team of experts/non-experts and stakeholders, or as a more direct synthesis of understanding by a single expert or small team working closely together. Consensus-based mapping can take the form of interactive brainstorming sessions in a workshop setting but might also be accomplished by comparison and merging of maps produced independently by a set of experts. These options are particularly suited to cases where the system is not well understood or where they are likely to be differences of opinion. Systems that are relatively well understood might be more amenable to a more direct mapping by a small team working closely together, or even an individual expert.

**Stage 3: Choose between geographic or topological mapping**

Decide whether a geographic map or a topological map is appropriate: this will depend on the nature and scale of the application.

**Stage 4: Assemble the required information and source materials**

Assemble data sources, including large-scale base-mapping or aerial imagery (e.g. scanned aerial photographs, Google Maps images, airborne Lidar data); research papers and reports; quantitative datasets (e.g. sediment budgets, tidal and wave climate information, modelled sediment transport rates etc.); and other sources of information (e.g. historical photographs, anecdotal evidence). For geographic mapping, aerial or satellite imagery at a suitably high resolution can be loaded directly into CmapTools to provide a background on which system components can be arranged.

**Stage 5: Define features**

Identify principal coastal (and offshore) features along the contemporary shoreline. This can be done directly within CmapTools (with or without a digital base map loaded). For larger systems, however, it may be easier to set up a spreadsheet to hold both the feature- and element-level classification, along with any meta-data such as place names or map co-ordinates.

**Stage 6: Define elements**

Identify coastal (and offshore) elements associated with each feature, taking account of hinterland, backshore and foreshore characteristics.
Stage 7: Define interventions

Identify any structural or non-structural interventions. In some situations, a structure may replace an element in the natural cross-shore assemblage (e.g. a seawall may replace a cliff). Alternatively, interventions may act to constrain the behaviour of elements (e.g. in the case of beach recharge, which constitutes an additional sediment source within the littoral system).

Stage 8: Feature – element hierarchy mapping

At this stage, feature and element symbols need to be created within CmapTools based upon the coastal classification assembled in spreadsheet form (these may already have been created graphically if a separate spreadsheet database has not been created). It is important that mapping should conform exactly to the conventions set out in Figure 2.1. Groups of elements and interventions are then used to create what CmapTools terms ‘nested nodes’; these define their affiliation with higher-level features. Nested nodes (i.e. the features) can be expanded to reveal full element-level detail or collapsed to display only the features.

Stage 9: Link mapping

Connectivity is mapped at the element-level according to the link types given in Figure 2.1. Line weightings can optionally be used to denote the strength or either sediment transfers or influences if this level of understanding is available.

Stage 10: Rationalisation

Rationalisation of the elements is usually necessary to highlight the system structure and avoid a dense matrix of elements within each feature. Rationalisation involves merging adjacent elements that can be considered to behave as a single unit.

Stage 11: Labelling of features and elements

In CmapTools, geographic place names or other labels can be added to the feature or element symbols, and this can be selected to appear when these are pointed to by the screen cursor. Additional label text can also be added to the system maps to improve readability.

Stage 12: Addition of meta-data

CmapTools allows the inclusion of additional information within an undisplayed but searchable field. Geographic co-ordinates and hyperlinks to relevant images, research literature or datasets can be inserted here.
Figure 2.2 Flow chart for coastal system mapping procedure
3 Worked example: Alnmouth Bay, northeast England

3.1 Alnmouth Bay

This section presents a worked example in which part of Alnmouth Bay on the Northumberland coast of northeast England is mapped using the procedure set out in the previous section. This involves the import of an aerial photograph covering the southern part of the bay into CmapTools, and the identification of a set of system components and the links between them on top of this base image.

Figure 3.1 shows the entirety of Alnmouth Bay, which comprises two main headlands (Bolumer and Hauxley), separated by a sandy bay backed by low ground (Holocene infill). The headlands are composite features, and the associated geological control is largely the result of the limestone and grit shore platforms. Small beaches are generally limited to a superficial cover across the upper foreshore, which are then backed by modern dune or low cliff into older aeolian deposits. Figure 3.2 shows the southern part of the bay, between the Birling Carrs and Amble headlands. This contains the small estuary of the Coquet River.

Selection of this region of interest corresponds to Stage 1 of the coastal system mapping flowchart presented in Figure 2.2. For the purpose of Stage 2 of the flowchart let us assume that this exercise involves the synthesis of existing knowledge of geomorphological processes and landform evolution by a single ‘expert’.
Figure 3.1 Alnmouth Bay. Rectangle shows region of interest for tutorial example (image from Google Maps).
3.2 CmapTools software installation and start-up

A copy of the installer for CmapTools v4.17 (Windows) is included with this tutorial package. Newer versions of CmapTools and installers for MacOS-X, Linux and Solaris can be downloaded from [http://cmap.ihmc.us](http://cmap.ihmc.us).

On installation, a project directory is created to hold CmapTools project files. By default this is in a location such as:
An explorer window showing the contents of this directory is displayed at startup. Existing maps (Cmaps) can be selected and opened, and new maps created.

**Set up a new Cmap project.** From the explorer menu, select *File – New Cmap*. An untitled map window appears (Figure 3.3). Select *File – Save Cmap* from the menu of the Cmap window to open a dialogue that allows you to save this. Open up the Tutorial folder and enter the map location as *Alnmouth tutorial*.

![CmapTools explorer menu (displayed on startup) and untitled map window.](image)

**Import a geographical map base image.** The next stage of the process is to decide what kind of map we are going to produce (Figure 2.2, Stage 3). Here, we are going to construct a geographical map over a base image of the region of interest. For tutorial purposes, an image obtained from Google Maps ([http://maps.google.co.uk](http://maps.google.co.uk)) will comprise the main data source (Figure 2.2, Stage 4).

From the Cmap window menu, select *Format – Background – Add* to add in a background image on which to create the system map. The Tutorial project folder contains an Images directory that includes a digital aerial photograph (*Alnmouth.jpg*). Select this and it will appear as the background in the Cmap window (Figure 3.5). A Style Palette will also appear, and this allows the user to select different kinds of container, line and text. The palette has tabs for *Font* (includes typefaces, point size, bold, italic, underline, alignment options); *Object* (allows selection of different shapes, fill colours and shadow effects, and allows control over object alignment); *Line* (controls line colour, thickness, style, the form of curved lines, and the creation of arrowheads); and *Cmap* (which allows control over background colour, scaling and the background image). Hovering the cursor over any control prompts a brief ‘pop up’ summary of its purpose.
Identify feature-level system components. Stage 5 of the coastal mapping process (Figure 2.2) involves defining the principal coastal features with reference to the classification of Table 2.1.

The key features in the southern portion of Alnmouth Bay comprise, from North to South, the headland of Birling Carrs, the bay, the estuary of the Coquet River, and the
Amble headland. We should also include the offshore as a feature. In CmapTools, individual system 'components' are referred to as ‘concepts’. The blank map window invites the user to “double-click to create a concept”. Place the cursor next to the headland of Birling Carrs, double-click, and type 'HEADLAND' into the dialogue box that appears. Repeat for the other features, as shown in Figure 3.6. In Figure 3.6, additional text has been used to annotate feature place names for ease of reference. This information can also be added to individual feature labels. Simply select a feature, then from the main Cmap window pulldown menu, select Tools – Add info – and enter required description in the Mouse Info box. This will then be displayed when the cursor moves over a feature. Figure 3.6 shows this being done for the Birling Carrs headland.

Figure 3.6 Addition of labels for principal features, including ‘Mouse Over Info’ for the Birling Carrs headland

At this point it is appropriate to consult the set of mapping symbols (Figure 2.1). The convention is to use upper case text for feature labels, and for these to be contained within rectangular boxes. Any format changes can be made (either individually or to a group of features selected together) using the font, object, and line tabs of the Style Palette.

**Identify element-level components.** Stage 6 of the coastal mapping process (Figure 2.2) involves defining the elements associated with each feature, with reference to the classification of Table 2.2. Figure 3.7 shows the mapping of the cross-shore zonation of the Birling Carrs headland feature in terms of hinterland (high ground), backshore (here interpreted as dune) and foreshore (shore platform). Note also, how the object tab of the Style Palette has been used to define the correct ellipsoidal element symbols in accordance with Figure 2.1.
The above process is repeated for the other features. In the bay to the south, the cross-shore zonation changes from high ground – dune – beach in the north to low ground – dune – beach in the south (Figure 3.7).

**Figure 3.7** Addition of labels for principal elements of the Birling Carrs headland and the southern portion of Alnmouth Bay. Note use of correct ellipsoidal ‘element’ symbols.

**Identify interventions.** Stage 7 of the coastal mapping process (Figure 2.2) involves defining the structural and non-structural interventions associated with each feature, again with reference to the classification of Table 2.2. In this example, interventions are confined to the estuary of the Coquet River and the entrance to Warkworth harbour.

Figure 3.8 shows how the various elements and interventions might be mapped in this region. The estuary itself is simply defined in terms of a channel, tidal flat, saltmarsh and a low ground hinterland (on account of the reclaimed land behind flood embankments). The harbour jetties constitute major structural interventions. One documented non-structural intervention at this site is the recycling of sand that accumulates within the harbour to the updrift beach. Note the contrasting symbolic representation of the interventions according to the scheme of Figure 2.1.
Figure 3.8 Mapping of elements and interventions for the Coquet River estuary and Amble headland.

[NB: For more complex systems, or if topological rather than geographical mapping is being used, it may be better to record the result of Stages 5 through 7 on a spreadsheet. In this case, transfer of this information constitutes Stage 8 of the flowchart in Figure 2.2. In the present example, however, we can proceed directly to link mapping (Figure 2.2, Stage 9).]

At this stage it is convenient to formally group elements and interventions with their ‘parent’ features. CmapTools allows the creation of ‘nested nodes’ that are attached to a ‘parent node’. We can use this to create feature-level groupings. Simply select all the elements / interventions (and the label) of the feature (either with control-click, or by dragging a selection rectangle) and, from the menu bar, select Tools – Nested Node – Create. Figure 3.9 shows this in progress for the bay feature.

This will create a new feature container that can be re-formatted to comply with the scheme in Figure 2.1 (i.e. removal of the object background colour, and enforcement of a rectangular outline shape; line colour may also be changed to white if the background image is dark). The tab on the right hand edge of the feature box (Figure 3.10) allows the detail to be collapsed or expanded. In collapsed mode, the feature reverts to a single label, which should be renamed (i.e. replace the question marks, ‘????’, with ‘BAY’ in this case). As with the initial feature labels, ‘Mouse over info’ can be added to indicate place names when the cursor is moved over them.
Figure 3.9 Creation of a ‘nested node’ to group the component parts of the bay feature (which have previously been selected).

Figure 3.10 Newly-created bay feature, prior to formatting using Style Palette.
**Link mapping:** This involves defining the various linkages that connect system components at the element and intervention scale. In CmapTools, links are created by clicking on a starting component, clicking again on the arrow icon that appears at the top of the symbol, holding the *shift* key down, and clicking on a destination component.

[NB: If the shift key is not held down, the link is created together with a label box that accepts some text. Use of the latter is not formally part of the coastal system scheme procedure set out in our Figure 2.1, although it could be used to hold specific information if desired (e.g. quantitative data on sediment flows, where these are known).]

Figure 3.11 shows the details of link creation for the mapping of the cross-shore zonation of the Birling Carrs headland feature in terms of hinterland (high ground), backshore (here interpreted as dune) and foreshore (shore platform). Note also, how the *object* tab of the Style Palette has been used to define the correct ellipsoidal element symbols in accordance with Figure 2.1.

![Figure 3.11](image)

**Figure 3.11 Creating a link between high ground (hinterland) and dune (backshore).** Style Palette Line tab can be used to determine whether to draw arrowheads always (first option), under various conditions (options 2 and 3), or not to draw arrowheads (option 4; as indicated in figure). Directionality can also be determined once a given link is selected.

It is probably easiest to create all links initially using simple lines with no arrows to indicate direction. This can be done by checking the ‘Do not draw Arrowheads’ option on the Line tab of the Style Palette (Figure 3.11). Once all the links are in place, line styles can be changed to indicate whether links represent sediment transfers or influences, and to add directional (or bidirectional) arrows.

Figure 3.12 shows a full set of links defined for our tutorial example. Hinterland – backshore links are defined as non-directional influences, on the basis that no exchanges of material are currently taking place, and that the nature / direction of any influence is ambiguous (at least without further investigation). Shore platforms on the other hand, are considered to influence (though not supply sediment to) the backshore elements (in this case, old dunes, the persistence of which may be influenced by the dissipative effect of the platform). Beach – dune linkages are depicted as bi-directional sediment exchanges. The two jetties are considered to exert directed influences on the
position / stability of the estuary channel. Recycling constitutes a directed sediment transfer, and sediment transfer from beach to seabed and into the channel completes this sediment loop. A network of sediment transfers connects the estuary channel, tidal flat and saltmarsh elements. Finally, the resistant shore platform of the Birling Carrs headland is considered to influence the beach within the bay to the south. For clarity over the dark base image, the line colour has also been changed to white.

**Figure 3.12** Completed link mapping for the example system. Note use of solid and dashed lines for sediment and influence links and arrows to indicate direction of influence.

**Rationalisation:** The next task (Stage 10 in Figure 2.2) is to rationalise the map to remove any redundant elements (or interventions). The aim here is to represent the essence of the system and its functional links using the minimum number of components. The most obvious candidate for rationalisation is the beach within the bay, which might reasonably be supposed to function as a single landform. Likewise, the dune backshore here might similarly be rationalised (i.e. the two dune elements can be merged). Figure 3.13 shows the result. Some slight rearrangement of the various labels has also been carried out.
Figure 3.13 Rationalised map, with beach and dune elements of bay merged to preserve the essential structure of the system using the minimum number of elements.

Additional labelling: Additional text for geographic place names or other annotations can be added at this point (Stage 11 of Figure 2.2). Likewise, meta-data can be added.

Meta-data: The completed coastal system map can be used as a repository for various kinds of data, such as reports and images. For example, we might want to associate photographs taken of local details with the associated components of the map.

The tutorial project folder contains an Image directory that contains photographs of the Warkworth harbour jetties. Select the northern jetty symbol on the map, right-click the mouse button, and select Add & Edit Links to Resources. Navigate to the Images folder in the upper part of the dialogue box, select ‘North Jetty - photo1’ and click Add to List. The item is added to the list of resources below. Do the same for ‘North Jetty – photo2’. The list contains editable fields (Figure 3.14). Embedded resources can be accessed from within the map itself (Figure 3.15).
Figure 3.14 Linking of digital photograph resources to a specific system component using the *Add & Edit Links to Resources* option.

Figure 3.15 Viewing embedded photographic resources by selecting from list associated with system component. Image resource is associated with jetty structure (image courtesy of Royal Haskoning).
Demo animation: To view an animated movie of the process of map creation, close the current map and open the map ‘Alnmouth tutorial demo movie’. Then select Tools – Cmap Recorder from the menu. A movie player appears, from which a movie showing the sequential construction of the Alnmouth map can be played. The movie includes the stages described above, and adjustment of the layout to achieve a satisfactory visual appearance.

3.3 Concluding remarks

The tutorial illustrates the production of a geographical system map on the basis of a geomorphological reconnaissance accomplished using online aerial photographic resources (Google Maps; http://maps.google.co.uk/). Aerial imagery alone is often sufficient for a first-order mapping exercise. For more detailed investigations it will be necessary to refer to the scientific literature as well as first-hand experience.

Strict adherence to the procedures (especially the symbolic conventions of Figure 2.1 and the process summarised in Figure 2.2) should minimise inconsistencies in maps produced by different experts. There will always be scope for interpretation, of course, and maps produced by different individuals will invariably differ in detail. Rather than being seen as a limitation, ‘operator variance’ of this kind should, in fact, be viewed as an extremely valuable aspect of the knowledge formalisation process.

Coastal system mapping can be a highly effective tool for formalising knowledge contained in disparate scientific publications and research reports, and presenting this information in a way that emphasises large-scale behaviour. Comparison and subsequent merging of maps produced in isolation by a small team of experts can work well for small systems where the mapping effort is not demanding in terms of time and supporting resources. A group activity, where two or more experts work together to produce a map that reflects their shared opinions may work better for larger systems, where the creation of the map involves more time and effort.

Coastal system maps can be used to inform the selection and implementation of predictive modelling tools, such as historical trend analysis or numerical coastal morphodynamic models. A system map can provide the framework for more quantitative analysis of the sediment budget, and can aid the specification of appropriate process modules in a numerical simulation package (e.g. Walkden and Rossington, 2009) as well as being used to analyse system connectivity (e.g. results presented in Whitehouse et al., 2009).

In electronic form, CmapTools project files can function as a repository for the results of quantitative analyses and predictive modelling. For example, the system linkages can be annotated to include quantitative estimates of the sediment mass fluxes, and model results files and research reports can be linked to system components.
Frequently-asked questions

1. **Q:** The coastal system mapping methodology seems very useful but I find the CmapTools software hard to use. Why can’t I use pencil and paper?

   **A:** There is no problem with that. A pencil and paper exercise may be perfectly adequate provided the system is not too complex. But we recommend CmapTools for the production of visually consistent maps and as a means of organising background resources, such as photos and reports.

2. **Q:** How do I remove the background image if I want to print out just the map on its own?

   **A:** From the menu, select Format – Background – Remove. The background image will disappear. It can be added back in (or replaced) from the same menu. If you are using white lines and symbol outlines, these may also disappear! In this case, select Edit – Select Connections to highlight all the linkages and edit the line colour using the Style Palette. You can do the same for the feature boxes via Edit – Select Concepts.

3. **Q:** All my links seem to have a ???? box in the middle!

   **A:** Hold the shift key down while creating the link.

4. **Q:** How do I produce a graphic that I can put into a report?

   **A:** To produce a jpeg format image from the current map, select File – Export Cmap as – Image file from menu. There are options for the quality / resolution of the image file.

5. **Q:** I know this site well and would have mapped the Alnmouth Bay coastal features and elements differently!

   **A:** This is not a problem. The tutorial example has been mapped quite simply without reference to complex background information. Different ‘experts’ will invariably come up with different maps. The import thing is to adhere to the methodology (especially Figures 2.1 and 2.2) closely so that maps are at least produced to the same standards. Comparing maps reveals differences in opinion, hopefully providing the basis for the emergence of a consensus. It might, however, indicate areas that we don’t know enough about.

6. **Q:** I don’t have enough background in geomorphology and coastal processes to fully understand the system that I am trying to map.

   **A:** The methodology is based on a fairly simple classificatory approach and does not require much expertise. However, some geomorphological expertise is extremely useful, especially when the methodology is being undertaken as part of a project workshop.
References


Would you like to find out more about us, or about your environment?

Then call us on
08708 506 506* (Mon-Fri 8-6)

email
enquiries@environment-agency.gov.uk

or visit our website
www.environment-agency.gov.uk

incident hotline 0800 80 70 60 (24hrs)
floodline 0845 988 1188

* Approximate call costs: 8p plus 6p per minute (standard landline).
Please note charges will vary across telephone providers.